REMARKS

Claims 1, 3, 4, 6, 7, 8-31, and 38-43 are pending. Claims 2, 5, and 32-37 have been cancelled without prejudice or disclaimer. Initially, Applicants thank the Examiner for providing an English-language translation of JP 60-067696A (JP '636) by facsimile on May 11, 2005. Coincidentally, Applicant also obtained a translation of JP '636 and enclose it in a concurrently filed IDS.

Claim 1 was amended to recite a Mn range supported by original claims 5-6 and a T39 and T351 temper condition of Claim 2.

In new Claim 38 the 0.14 lower Zr limit is supported at page 10, Table 1, the upper limit is in the base claim.

In Claim 39 the 0.40 lower Mn limit is supported at page 10, Table 1, the upper limit is in the base claim.

In Claim 40 the 3.8 lower Cu limit is supported at the original base claim, the upper limit is supported by original Claim 9.

Claim 41 is supported by original Claim 2.

Claim 42 is supported as is Claim 1.

Claim 43 is supported by original Claim 2.

It is respectfully submitted no new matter is presented by these claims.

I. Election/Restriction

In response to the Election Requirement stated in the Office Action, Applicants confirm the election of Group I, drawn to an aluminum alloy product, Claims 1-31. Accordingly, claims 32-37 have been cancelled without prejudice or disclaimer. Applicants expressly reserve the right to file one or more divisional or continuation applications presenting the now-cancelled claims.

II. 35 USC § 102

Claims 1-8 and 11-31 stand rejected under 35 USC § 102(e) as allegedly being anticipated by U.S. Publication No. 2004/0060618. However, the rejected claims find support in

the priority application, i.e., EP 0278443.5, having a filing date of August 20, 2002. Thus, US '618, having a filing date of August 13, 2003 is not a proper reference.

Claim 1 is supported as follows, wherein page numbers refer to the certified copy of the priority document filed September 26, 2003:

Present Claim 1 (amendments shown with underlining and striking out)	Support from EP0278443.5 Claim 1	Support elsewhere in EP027844.3
A high damage tolerant Al-Cu 2xxx-series alloy rolled product having a high toughness and an improved fatigue crack growth resistance, comprising the following composition (in weight percent):	High damage tolerant Al-Cu alloy having a high toughness and an improved fatigue crack growth resistance, comprising essentially the following composition (in weight percent):	Page 1, first paragraph states. "More specifically, the present invention relates to a high damage tolerant Al-Cu-Mg alloy designated by the Aluminum Association ("AA") 2xxx-series...."
Cu: 3.8 - 4.7	Cu: 3.8 - 4.7	
Mg: 1.0 - 1.6	Mg: 1.0 - 1.6	
Zr: 0.06 - 0.18	Zr: 0.06 - 0.18	
Mn: > 0.15 - 0.45 ~~>0 - 0.50~~	Mn: >0 - 0.50, preferably >0.15	upper limit supported by claim 3
Cr < 0.15		Page 7, last paragraph Cr+Zr ≤0.20% or Cr+Zr 0.05 to 0.15% coupled with page 11, Table 1, Alloy 8 having 0% Zr.
Fe: ≤ 0.15	Fe: ≤ 0.15	
Si: ≤ 0.15	Si: ≤ 0.15	
the balance essentially aluminum and incidental elements and impurities, wherein the alloy product comprises Mn-containing dispersoids and Zr-containing dispersoids, and	and Mn-containing dispersoids, the balance essentially aluminum and incidental elements and impurities, wherein the Mn-containing dispersoids are at least partially replaced by Zr-containing dispersoids.	
wherein the alloy product is in a T39 or T351 [[T3]] temper.		* see below
* Page 6, middle paragraph of EP 02078443.5 mentions the product in T3 temper. Page 11 discloses examples in the T351 temper. Present claim 1 recites 2000 series alloys and page 1, second paragraph states alloys 2024, 2324 and 2524 have useful strength and toughness properties in T3, T39 and T351 tempers. It is respectfully submitted disclosure of T3 and T351 for the 2000 series alloys of the present invention, plus the disclosure that it is known to produce alloys 2024, 2324 and 2524 to have useful strength and toughness properties in T3, T39 and T351 tempers shows an alloy of the present invention in T39 temper was in the possession of the present inventor.		

For the Examiner's information, T3 applies to products that are cold-worked specifically to improve strength after solution heat treatment and for which mechanical properties have been stabilized by room-temperature aging. It also applies to products in which the effects of cold work, imparted by flattening or straightening, are accounted for in specified property limits (ATTACHMENT I, ASM Specialty Handbook, Aluminum and Aluminum Alloys, p. 29).

Tx51 applies specifically to plate, to rolled or cold-finished rod and bar, to die or ring forgings, and to rolled rings. These products receive no further straightening after stretching (ATTACHMENT I, ASM Specialty Handbook, Aluminum and Aluminum Alloys, p. 30).

The alloys 2324-T39 and 2224-T3 were developed by modifying the composition and processing of standard 2024. The amount of cold work applied after quenching and prior to aging was increased from the 1–3 percent used for 2024-T351 plate to about 9 percent. The allowable limits of iron and silicon impurities were reduced, and composition and processing were modified to minimize constituent particles and to improve fracture toughness and decrease fatigue crack growth rate. Processing conditions were also modified for extrusions in order to retain the deformation crystallographic texture for added texture strengthening . (ATTACHMENT II, New Materials for Next-Generation Commercial Transports, National Materials Advisory Board, National Academy Press, p. 26 (1996))

Support for present claims 1, 3, 4, 6-31 in the priority document is detailed in the following table:

Present Claim No.	Support Location in Priority Document
1	See above Table 1
3	Claim 2
4	Page 8, last paragraph
6	Page 7, first paragraph
7	Page 7, first paragraph
8	lower limit, page 7, second paragraph;

	upper limit Claim 1
9	Claim 4
10	Claim 4
11	Claim 5
12	Claim 5
13	Page 8
14	Page 8
15	Claim 6
16	Page 7, last paragraph showing Zr+Cr is in a range of 0.05 to 0.15% coupled with page 11, Table 1, Alloy 8 having 0% Zr.
17	Page 7, last paragraph
18	Page 7, last paragraph
19	Page 9, first paragraph indicates Ag may be present. This implies alloys may be made lacking Ag.
20	Page 9, first paragraph
21	-
22	-
23	-
24	Page 5, second full paragraph and page 12 listing ASTM E-647
25	Page 5, second full paragraph and page 12 listing ASTM E-647
26	Claim 8; for tempers see above discussion of Claim 1
27	Page 10, lines 22-23
28	Page 10, lines 24-25
29	Page 10, lines 25-28

30	Page 10, lines 25-28
31	See above discussion of Claim 1

Reconsideration is respectfully requested.

III. 35 USC § 102/§ 103

A. § 102

Claims 1, 5, 8, 9, 11-20 and 31 stand rejected under 35 USC § 102(b) as allegedly being anticipated by or in the alternative, under 35 USC § 103(a), as being unpatentable over JP 60-067696A.

Claim 1 has been amended to recite a manganese range of greater than 0.15 to 0.45% by taking the upper end of this range from Claim 6 which was not rejected in view of this reference. Thus, it is respectfully submitted this rejection is overcome.

B. § 103

Moreover, as regards the § 103 rejection, it is respectfully submitted the amendment to recite the Claim 6 Mn range upper end overcomes this rejection. Moreover, JP '636 discloses an aluminum alloy product for video tape record (VTR) cylinders and providing a reduced friction coefficient for good tape-run with little tape abrasion. This field of technology is non-analogous to the field of the present invention, namely aerospace grade rolled aluminum alloy products.

JP '636 discloses an aluminum alloy product for video tape record (VTR) cylinders. The alloy provides a reduced friction coefficient for good tape-run with little tape abrasion. This field of technology is non-analogous to the field of the present invention, namely aerospace grade rolled aluminum alloy products.

JP '636 is silent about any engineering property relevant for use in constructing aircraft, namely high damage tolerance such as toughness and fatigue crack growth resistance and good strength levels. The first paragraph of the present application explains such properties. JP '636 is concerned with machinability and low coefficient of friction (see Applicant's translation page 3, Object).

Furthermore, the presently claimed products relate to rolled products. In contrast, JP '636 discloses extruded alloy products, which after extrusion are also drawn and forged (see

Applicant's translation page 5, production process steps C to E). Typical dimensions of the product are in the range of 45 mm diameter (see Applicant's translation page 6, line 13) which renders the product unsuitable for fuselage skin or lower wing skin of an aircraft (see the first paragraph of the present application and present Claims 29 and 30).

The dimensions disclosed in JP '636 do not even allow for the measurement of relevant properties, in particular fatigue crack growth, as this is typically carried out on sheet having dimensions of 80 mm wide (see claims 24 and 25 and paragraph [0107] of the present application).

In addition, the extruded and forged products of JP '636 are aged to a T6 temper to achieve maximum strength. In contrast, the present rolled products are provided in the T3 family of tempers, namely T39 or T351, to provide an improved balance of strength and other engineering properties.

IV. 35 USC § 103

A. Heymes et al. in view of JP '574

Claims 1-31 stand rejected under 35 USC § 103(a) as being unpatentable over Heymes et al. (U.S. Patent No. 6,077,363) in view of JP 07-252574 (JP '574). The Office Action asserts Heymes et al. teaches each feature of the rejected claims, except for the addition of Zr and/or Cr to the alloy, for which purpose JP '574 is cited.

Applicants direct the Examiner's attention to paragraph [0004] of JP '574 which discusses Fe and Si ranges limited to 0.15% or less, and 0.1% or less, respectively. However, such a description is referring to the approach described by JP 55-47371. In fact, the invention of JP '574 is concerned with cooling rate conditions when the value of [Fe]+[Si] is between 0.4 and 2%. Specifically, none of the Examples (as detailed in Table 1) include both Fe and Si less than or equal to 0.15%.

Paragraph [0004] of JP '574 refers to the prior art teaching of JP 55-47371 that the Fe and Si-content in this type of alloy should be limited to 0.15% or less for Fe and 0.1% or less for Si. These ranges are much in line with the presently claimed ranges, however, the last line of

this paragraph [0004] reads that aluminum metal with such very high purity, "becomes cost quantity, and is <u>lacking in practicality</u>".

Thus, JP '574 actually teaches away from the presently recited low Fe and Si ranges by presenting alloys outside the presently recited ranges, in combination with processing steps including a cooling rate during casting (see paragraph [0017]). This effect occurs when Fe+Si>0.4% (see, e.g., Fig. 1). None of the Examples show the presently recited Mn, Fe and Si levels, as all have Fe levels of 0.2% or more.

Furthermore, one of ordinary skill in the art would <u>not</u> look to JP '574 when attempting to increase the strength and toughness of an aluminum alloy product, as this reference teaches the possible addition of Mn and/or Zr and/or Cr <u>only in combination</u> with high levels of Fe and Si.

In contrast, the present specification shows that low levels of Fe and Si (each less than 0.15%), in combination with Mn (>0.15-0.45%) and Zr (0.16-0.18%), not only works, but achieves significant advantages over prior art alloys.

The selection of the presently recited ranges provides unexpected improvement in fatigue crack growth rate. Applicants direct the Examiner's attention to paragraph nos. 65, 108 and 109, as well as to Table 3 of the present application. These sections show the unexpected improvement over a conventional AA2024 alloy (wherein the Mn and Zr values are not within the presently recited ranges). The data shows unexpected improvement when the Mn and Zr levels are selected such that Mn is between 0.21 and 0.43%, while simultaneously, Zr is between 0.06 and 0.14. It is respectfully submitted this data is commensurate in scope with the present claims.

B. <u>Rioja</u>

Claims 1, 3-20 and 24-31 stand rejected under 35 USC § 103(a) as being unpatentable over Rioja (U.S. Patent No. 6,562,154). However, as the subject matter of (now-cancelled) claim 2 has been incorporated into claim 1, reconsideration is respectfully requested.

Specifically, claim 1 now recites the alloy product is in a T39 or T351 temper, as neither taught nor suggested by this reference.

C. Warner et al.

Claims 1, 2, 5, 8-20 and 24-31 stand rejected under 35 USC § 103(a) as being unpatentable over Warner et al. (U.S. Patent No. 6,602,361).

Claim 6 was not included in this rejection. Thus, as the reference teaches a Mn range of 0.5-0.8, and amended Claim 1 recites a maximum of 0.45%, as originally presented by Claim 6, reconsideration is respectfully requested.

D. JP '636

Claim 10 stands rejected under 35 USC § 103(a) as being unpatentable over JP '636. Base Claim 1 has been amended to recite a manganese range of greater than 0.15 to 0.45% by taking the upper end of this range from Claim 6 which was not rejected in view of this reference. Moreover, this reference is non-analogous to the present invention for reasons listed above. Thus, it is respectfully submitted this rejection is overcome.

E. JP '636 in view of "Aluminum Alloys"

Claims 27-30 stand rejected under 35 USC § 103(a) as being unpatentable over JP '636 in view of "Aluminum Alloys," pgs. 63-64. As mentioned above, Claim 1 has been amended to recite a manganese range of greater than 0.15 to 0.45% by taking the upper end of this range from Claim 6 which was not rejected in view of either of these references. Moreover, JP '636 is non-analogous to the present invention for reasons listed above. Thus, it is respectfully submitted this rejection is overcome.

V. Provisional Double Patenting

Claims 1-8 and 11-31 stand provisionally rejected under the judicially created doctrine of obvious-type double patenting, as being unpatentable over claims 1-36 of US '618. Claims 1-31 stand provisionally rejected under the judicially created doctrine of obvious-type double patenting, as being unpatentable over claims 1-23 of copending U.S. Publication No. 2004/0112480 (U.S. Appl. No. 10/642,518). Applicants shall file any necessary Terminal Disclaimers when required.

V. Conclusion

In view of the above, it is respectfully submitted that all objections and rejections are overcome. Thus, a Notice of Allowance is respectfully requested.

Respectfully submitted,

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ATTACHMENT I,
ASM Specialty Handbook, Aluminum and Aluminum Alloys, p.29- 30 (1993)

ASM Specialty Handbook®

Aluminum and Aluminum Alloys

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temper designations have already been assigned for wrought products in all alloys:

- *Hx11* applies to products that incur sufficient strain hardening after final annealing to fail to qualify as 0 temper, but not so much or so consistent an amount of strain hardening to qualify as Hx1 temper.
- *H112* pertains to products that may acquire some strain hardening during working at elevated temperature and for which there are mechanical property limits.
- *Patterned or Embossed Sheet.* Table 5 lists the three-digit H temper designations that have been assigned to patterned or embossed sheet.

System for Heat-Treatable Alloys

The temper designation system for wrought and cast products that are strengthened by heat treatment employs the W and T designations described in the section "Basic Temper Designations" in this article. The W designation denotes an unstable temper, whereas the T designation denotes a stable temper other than F, O, or H. The T is followed by a numeral from 1 to 10, each numeral indicating a specific sequence of basic treatments. A description of how aluminum alloys are classified as heat-treatable versus non-heat-treatable can be found in the article "General Introduction" in this volume.

T1, Cooled from an Elevated-Temperature Shaping Process and Naturally Aged to a Substantially Stable Condition. This designation applies to products that are not cold-worked after an elevated-temperature shaping process such as casting or extrusion and for which mechanical properties have been stabilized by room-temperature aging. It also applies to products that are flattened or straightened after cooling from the shaping process, for which the effects of the cold work imparted by flattening or straightening are not accounted for in specific property limits.

T2, Cooled from an Elevated-Temperature Shaping Process, Cold-Worked, and Naturally Aged to a Substantially Stable Condition. This variation refers to products that are cold-worked specifically to improved strength after cooling from a hot-working process such as rolling or extrusion and for which mechanical properties have been stabilized by room-temperature aging. It also applies to products in which the effects of cold work, imparted by flattening or straightening, are accounted for in specified property limits.

T3, Solution Heat-Treated, Cold-Worked, and Naturally Aged to a Substantially Stable Condition. T3 applies to products that are cold-worked specifically to improve strength after solution heat treatment and for which mechanical properties have been stabilized by room-temperature aging. It also applies to products in which the effects of cold work, imparted by flattening or straightening, are accounted for in specified property limits.

T4, Solution Heat-Treated and Naturally Aged to a Substantially Stable Condition. This signifies products that are not cold-worked after solution heat treatment and for which mechanical properties have been stabilized by room-temperature aging. If the products are flattened or straightened, the effects of the cold work imparted by flattening or straightening are not accounted for in specified property limits.

T5, Cooled from an Elevated-Temperature Shaping Process and Artificially Aged. T5 includes products that are not cold-worked after an elevated-temperature shaping process such as casting or extrusion and for which mechanical properties have been substantially improved by precipitation heat treatment. If the products are flattened or straightened after cooling from the shaping process, the effects of the cold work imparted by flattening or straightening are not accounted for in specified property limits.

T6, Solution Heat-Treated and Artificially Aged. This group encompasses products that are not cold-worked after solution heat treatment and for which mechanical properties or dimensional stability, or both, have been substantially improved by precipitation heat treatment. If the products are flattened or straightened, the

Table 4 ISO equivalents of wrought Aluminum Association international alloy designations

Aluminum Association international designation	ISO designation
1050A	Al 99.5
1060	Al 99.6
1070A	Al 99.7
1080A	Al 99.8
1100	Al 99.0 Cu
1200	Al 99.0
1350	E-Al 99.5
. . .	Al 99.3
1370	E-Al 99.7
2011	Al Cu6BiPb
2014	Al Cu4SiMg
2014A	Al Cu4SiMg(A)
2017	Al Cu4MgSi
2017A	Al Cu4MgSi(A)
2024	Al Cu4Mg1
2030	Al Cu4PbMg
2117	Al Cu2.5Mg
2219	Al Cu6Mn
3003	Al Mn1Cu
3004	Al Mn1Mg1
3005	Al Mn1Mg0.5
3103	Al Mn1
3105	Al Mn0.5Mg0.5
4043	Al Si5
4043A	Al Si5(A)
4047	Al Si12
4047A	Al Si12(A)
5005	Al Mg1(B)
5050	Al Mg1.5(C)
5052	Al Mg2.5
5056	Al Mg5Cr
5056A	Al Mg5
5083	Al Mg4.5Mn0.7
5086	Al Mg4
5154	Al Mg3.5
5154A	Al Mg3.5(A)
5183	Al Mg4.5Mn0.7(A)
5251	Al Mg2
5356	Al Mg5Cr(A)
5454	Al Mg3Mn
5456	Al Mg5Mn
5554	Al Mg3Mn(A)
5754	Al Mg3
6005	Al SiMg
6005A	Al SiMg(A)
6060	Al MgSi
6061	Al Mg1SiCu
6063	Al Mg0.7Si
6063A	Al Mg0.7Si(A)
6082	Al Si1MgMn
6101	E-Al MgSi
6101A	E-Al MgSi(A)
6181	Al Si1Mg0.8
6262	Al Mg1SiPb
6351	Al Si1Mg0.5Mn
7005	Al Zn4.5Mg1.5Mn
7010	Al Zn6MgCu
7020	Al Zn4.5Mg1
7049A	Al Zn8MgCu
7050	Al Zn6CuMgZr
7075	Al Zn5.5MgCu
7178	Al Zn7MgCu
7475	Al Zn5.5MgCu(A)
. . .	Al Zn4Mg1.5Mn
. . .	Al Zn6MgCuMn

Table 5 H temper designations for aluminum and aluminum alloy patterned or embossed sheet

Patterned or embossed sheet	Temper of sheet from which textured sheet was fabricated
H114	O
H124	H11
H224	H21
H324	H31
H134	H12
H234	H22
H334	H32
H144	H13
H244	H23
H344	H33
H154	H14
H254	H24
H354	H34
H164	H15
H264	H25
H364	H35
H174	H16
H274	H26
H374	H36
H184	H17
H284	H27
H384	H37
H194	H18
H294	H28
H394	H38
H195	H19
H295	H29
H395	H39

Source: Ref 1

effects of the cold work imparted by flattening or straightening are not accounted for in specified property limits.

T7, Solution Heat-Treated and Overaged or Stabilized. T7 applies to wrought products that have been precipitation heat-treated beyond the point of maximum strength to provide some special characteristic, such as enhanced resistance to stress-corrosion cracking or exfoliation corrosion (both of these modes of corrosion are described in the article "Corrosion Behavior" in this Volume). It applies to cast products that are artificially aged after solution heat treatment to provide dimensional and strength stability.

T8, Solution Heat-Treated, Cold-Worked, and Artificially Aged. This designation applies to products that are cold-worked specifically to improve strength after solution heat treatment and for which mechanical properties or dimensional stability, or both, have been substantially improved by precipitation heat treatment. The effects of cold work, including any cold work imparted by flattening or straightening, are accounted for in specified property limits.

T9, Solution Heat-Treated, Artificially Aged, and Cold-Worked. This grouping is comprised of products that are cold-worked specifically to improve strength after they have been precipitation heat-treated.

T10, Cooled from an Elevated-Temperature Shaping Process, Cold-Worked, and Artificially Aged. T10 identifies products that are cold-worked specifically to improve strength after cooling from a hot-working process such as rolling or extrusion and for which mechanical properties have been substantially improved by precipitation heat treatment. The effects of cold work, including any cold work imparted by flattening or straightening, are accounted for in specified property limits.

Additional T Temper Variations. When it is desirable to identify a variation of one of the ten major T tempers described above, additional digits, the first of which cannot be zero, may be added to the designation.

Specific sets of additional digits have been assigned to stress-relieved wrought products:

Stress-Relieved by Stretching, Compressing, or Combination of Stretching and Compressing. This designation applies to the following products when stretched to the indicated amounts after solution heat treatment or after cooling from an elevated-temperature shaping process:

Product form	Permanent set, %
Plate	1½-3
Rod, bar, shapes, and extruded tube	1-3
Drawn tube	½-3

- Tx51 applies specifically to plate, to rolled or cold-finished rod and bar, to die or ring forgings, and to rolled rings. These products receive no further straightening after stretching.
- Tx510 applies to extruded rod, bar, shapes and tubing, and to drawn tubing. Products in this temper receive no further straightening after stretching.
- Tx511 refers to products that may receive minor straightening after stretching to comply with standard tolerances.

One variation involves stress relief by compressing:

- Tx52 applies to products that are stress-relieved by compressing after solution heat treatment or after cooling from a hot-working process to produce a permanent set of 1 to 5%.

The next designation is used for products that are stress-relieved by combining stretching and compressing:

- Tx54 applies to die forgings that are stress-relieved by restriking cold in the finish die. (These same digits—and 51, 52, and 54—may be added to the designation W to indicate unstable solution heat-treated and stress-relieved tempers.)

Temper designations have been assigned to wrought products heat-treated from the O or the F temper to demonstrate response to heat treatment:

- T42 means solution heat-treated from the O or the F temper to demonstrate response to heat treatment and naturally aged to a substantially stable condition.
- T62 means solution heat-treated from the O or the F temper to demonstrate response to heat treatment and artificially aged.

Temper designations T42 and T62 also may be applied to wrought products heat-treated from any temper by the user when such heat treatment results in the mechanical properties applicable to these tempers.

System for Annealed Products

A digit following the O indicated a product in annealed condition having special characteristics. For example, for heat-treatable alloys, O1 indicates a product that has been heat-treated at approximately the same time and temperature required for solution heat treatment and then air-cooled to room temperature; this designation applies to products that are to be machined prior to solution heat treatment by the user. Mechanical property limits are not applicable.

Designation of Unregistered Tempers

The letter P has been assigned to denote H, T, and O temper variations that are negotiated between manufacturer and purchaser. The letter P follows the temper designation that most nearly pertains. The use of this type of designation includes situations where:

- The use of the temper is sufficiently limited to preclude its registration.
- The test conditions are different from those required for registration with the Aluminum Association.
- The mechanical property limits are not established on the same basis as required for registration with the Aluminum Association.

Foreign Temper Designations

Unlike the agreement relating to wrought alloy designations, there is no Declaration of Accord for an international system of tempers to be registered with the Aluminum Association by foreign organizations. For the most part, the ANSI system is used, but because there is no international accord, reference to ANSI H35.1 properties and characteristics of aluminum alloy tempers registered with the Aluminum Association under ANSI 35.1 may not always reflect actual properties and characteristics associated with the particular alloy temper. In addition, temper designations may be created that are not registered with the Aluminum Association.

ACKNOWLEDGMENT

The information in this article is largely taken from R.B.C. Cayless, Alloy and Temper Designation Systems for Aluminum and Aluminum Alloys, Volume 2 of the *ASM Handbook* (formerly *Metals Handbook*, 10th Edition), ASM International, 1990, p 15-28.

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ATTACHMENT II,
New Materials for Next-Generation Commercial Transports, National Materials Advisory Board, National Academy Press, p. 26 (1996)

NEW MATERIALS FOR NEXT-GENERATION COMMERCIAL TRANSPORTS

Committee on New Materials for Advanced Civil Aircraft

National Materials Advisory Board
Aeronautics and Space Engineering Board

Commission on Engineering and Technical Systems

National Research Council

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New Materials for Next-Generation Commercial Transports (1996)

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Metallic Materials and Processes

Aircraft alloy materials and processing technology has been advancing steadily with each new aircraft model. Important alloys in commercial transport applications include high-performance aluminum alloys, high-strength steels, and titanium alloys. Significant progress is being made in developing alloys with improved strength, toughness, corrosion resistance, and producibility. Advances have been achieved primarily through incremental improvements to already-developed alloys. Manufacturing process development has been emphasizing low-cost approaches such as net-shape processing (casting and forging), improved forming methods, and high-speed machining. This chapter describes developments and trends in metallic alloy materials and processes.

ALUMINUM ALLOYS

The primary use of high-strength aluminum alloys is in aircraft construction; the airframe of modern aircraft is approximately 80 percent aluminum by weight (Marceau, 1994). Traditionally, the structural aluminum alloys in aircraft have been 2024 in damage-critical areas and 7075 in strength-critical areas (Starke and Staley, 1996).

The goal of aircraft designers to improve durability and save weight has led to the development of new aluminum alloys that provide improved combinations of specific strength, durability, and damage tolerance. Most often, the newer alloys are variants of older 2XXX- and 7XXX-series alloys—but with tighter controls on chemistry and processing parameters. For instance, the upper and lower wing structures of the Boeing 757 and 767 are manufactured with improved alloys relative to the older Boeing 747. The improved alloys include 7150-T6 plate and extrusions (upper wing) and 2324 plate and 2224 extrusions (lower wing). Alloy 7150-T6 is a modification of the 7050-T74 product. It is aged to a higher strength and is processed to control the grain structure and degree of recrystallization (Staley, 1992). The T6 temper results in a higher strength than the T74 temper, and a new aging treatment (T61 temper) was developed to provide one letter-grade better in the rating system used to describe exfoliation corrosion. Alloy 7150-T61 plate and extrusions are also used on the McDonnell Douglas MD-11. The tighter controls on chemistry and processing parameters may cause an increase in the cost of the material, but production applications of improved alloys show that this cost can be offset by benefits in performance or durability.

Improved Strength and Corrosion Resistance

The conventional T76 and T73 tempers used to develop high resistance to exfoliation corrosion and to stress corrosion cracking in the short transverse direction of 7XXX alloys are associated with a 10–15 percent reduction in strength compared with the peak-aged T6 temper. To address this reduction, the T77 temper has been developed for the 7150 and 7055 alloys. The 7150-T77 plate and extrusions have the strength and fracture toughness of 7150-T6 and -T61, but with the exfoliation and stress corrosion resistance of 7075-T76. The alloy 7055 relies on strict control of solute elements and thermomechanical processing to produce a material that has a higher strength than that of 7178-T6, along with improvements in exfoliation corrosion, stress corrosion cracking susceptibility, fracture toughness, and fatigue resistance (Staley, 1994).

Improved Durability and Damage Tolerance

The alloys 2324-T39 and 2224-T3 were developed by modifying the composition and processing of standard 2024. The amount of cold work applied after quenching and prior to aging was increased from the 1–3 percent used for 2024-T351 plate to about 9 percent. The allowable limits of iron and silicon impurities were reduced, and composition and processing were modified to minimize constituent particles and to improve fracture toughness and decrease fatigue crack growth rate. Processing conditions were also modified for extrusions in order to retain the deformation crystallographic texture for added texture strengthening (Staley and Rolf, 1993).

Boeing is using a new Alcoa alloy, C188, for the fuselage of the 777. This alloy falls into the 2XXX-series family and has stricter chemistry and process controls than normal airframe alloys. It has a 17 percent improvement in toughness and a 60 percent slower fatigue crack growth compared with 2024-T3.

Since the aluminum alloys discussed above are variants of or improvements over conventional aluminum alloys that are